CNTT-E-140

BASIC ELECTRICITY AND ELECTRONICS

STUDENT HANDOUT NO. 303

SUMMARIES PROGRESS CHECKS AND JOB PROGRAMS FOR MODULES

30-2A & 30-3

JUNE 1984

ADDENDUM

SUMMARY

Lesson 30-2A

Transistor, Voltage and Current Regulators

Now that you have studied the operation of common electronic circuits that are used in voltage and current regulators, it is time to incorporate them into an operational device. The block diagram for the transistor regulator used in the NIDA power supply trainer is shown in Figure 1. As you study the diagram, refer to the fold-out schematic for the circuit at the rear of this addendum.

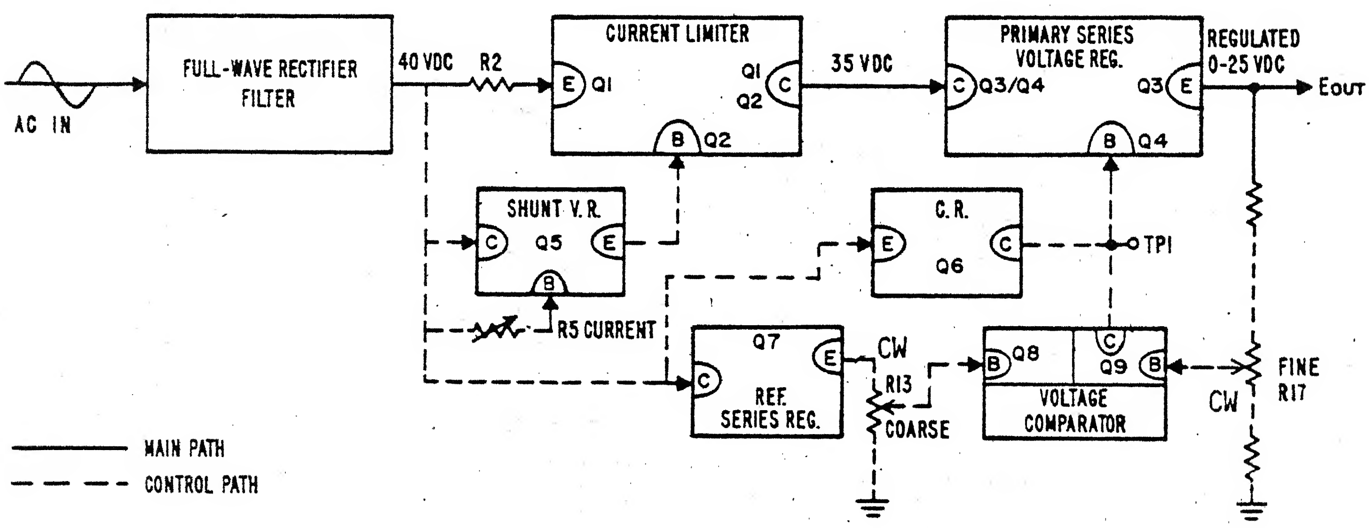


Figure 1

BLOCK DIAGRAM - TRANSISTOR VOLTAGE REGULATOR

As shown in Figure 1, AC power is applied to a conventional full-wave rectifier-filter stage which produces 40 VDC unregulated output. This voltage is fed to the series connected current limiter and primary series voltage regulator stages.

The current limiter stage limits the output current from the transistor voltage regulator to a maximum of 1.5 amperes. The output voltage from the shunt voltage regulator stage is used to control Darlington connected transistors Q1 and Q2 in this process. R5, the Current control on the front panel of the trainer, determines the maximum current point. Once R5 is set, the current limiter monitors the load current through R2 and automatically increases the resistance of Q1 when the current limit point is reached.

The primary series voltage regulator stage controls the value of the output voltage from the regulator as determined by the settings of R13 (Coarse) and R17 (Fine) front panel controls on the NIDA 201 power supply trainer. In addition, this stage receives the correction voltage from the voltage comparator stage to maintain a constant output voltage with changes in load current and AC input voltage.

The voltage comparator stage develops the correction voltage by comparing the error voltage on the base of Q9 with the reference voltage on the base of Q8.

Current regulator stage Q6 and associated components act as the collector load resistance for Q9 and thereby increase the sensitivity of the voltage comparator stage.

Q7 and its associated components make up the reference series voltage regulator stage and provide a regulated voltage source for the voltage comparator.

Coarse voltage control (R13) sets the reference voltage level developed at the base of Q8 in the voltage comparator. This control provides for large changes in the output voltage (0-25 VDC) from the regulator. The action is produced by controlling the conduction level of Q8, Q9, Q4, and Q3.

In a similar manner, but to a smaller degree, the voltage selected by R17 directly affects the conduction of Q9, Q4, and Q3. With this control the output voltage may be adjusted a small amount around the voltage level set by the coarse voltage control.

When troubleshooting complex electronic equipment, the technician must be able to eliminate the "good from the bad" circuits to narrow the field of suspects. The elimination process is often the "key" to successful troubleshooting.

A common technique that is used in the process of elimination requires the manipulation of front panel controls on the faulty equipment. The three front panel controls on the NIDA 201 power supply trainer are Current, Coarse, and Fine voltage.

Figure 2 shows the block diagram of the transistor voltage regulator with the front panel controls circled. Refer to this diagram during the following discussion.

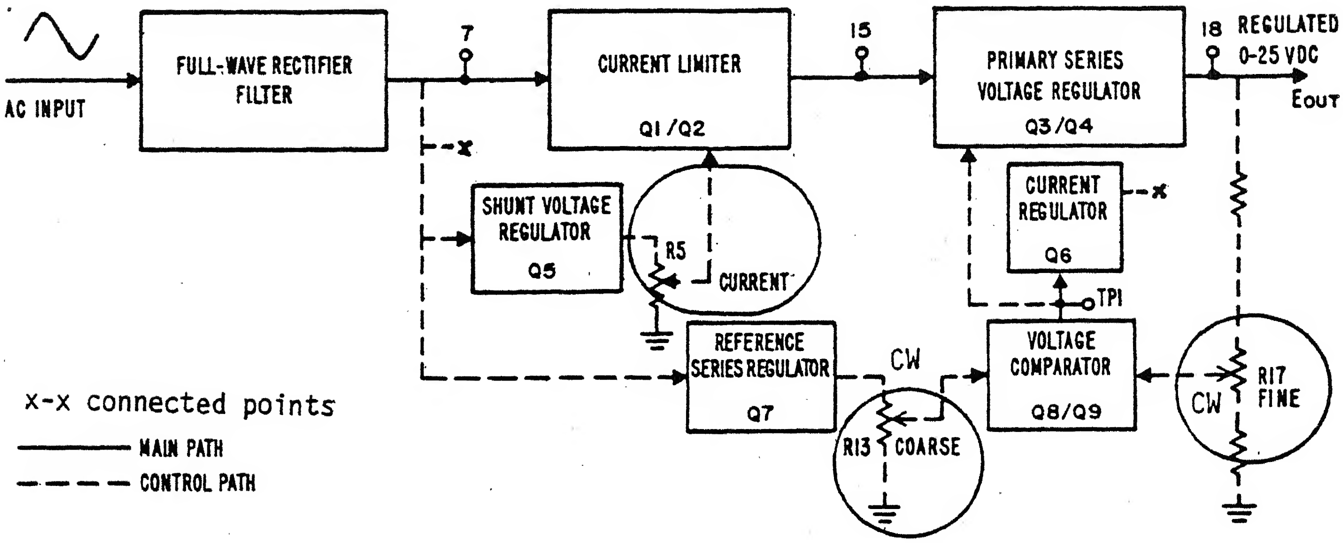


Figure 2

PC 201 BLOCK DIAGRAM - FRONT PANEL CONTROLS

Current Control (R5). This control should cause the output current and voltage to change from zero (0) to the maximum possible values if the shunt voltage regulator and current limiter stages are functional.

Coarse Voltage Control (R13). This control should cause the output voltage to change from zero (0) to about 25 VDC if the reference series voltage regulator, voltage comparator, current regulator, and primary series voltage regulator are functional.

Fine Voltage Control. (R17). This control should cause a small change in the output voltage if the voltage divider, voltage comparator, current regulator, and primary series voltage regulator are functional.

When the output voltage from the supply is zero (0), or front panel control adjustments provide no effect, you must take voltage measurements on one or more of the four test points on the PC 201 card. Figure 3 shows the position of the test points on the PC 201 transistor regulator block diagram.

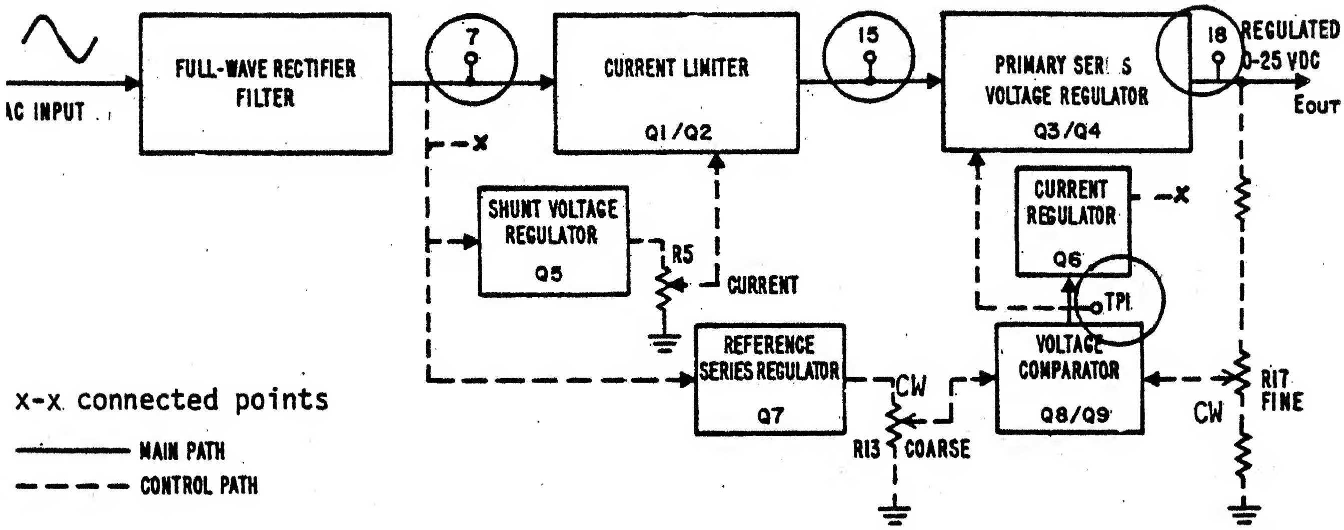


Figure 3

PC 201 BLOCK DIAGRAM - TEST POINTS

Pin 7. The voltage at this point is normally about 40 VDC if the full-wave rectifier-filter stages are functional.

Pin 15. The voltage at this point should vary between zero (0) and about 35 VDC if the current limiter and shunt voltage regulator are functional.

Pin 18. The voltage at this point is the DC output voltage from the regulator. If abnormal, a check at pin 15 will determine if the problem is in the primary series voltage regulator and associated control stages.

TP-1. This test point is the half-split point to isolate problems within the primary series voltage regulator and associated control stages.

When working with DC levels in this device, create your own voltage levels by slowly rotating the front panel controls. The changing DC levels, coupled with ICO logic, should enable you to isolate the faulty stage.

AT THIS TIME YOU MAY TAKE THE ADDENDUM PROGRESS CHECK, IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK ITEMS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

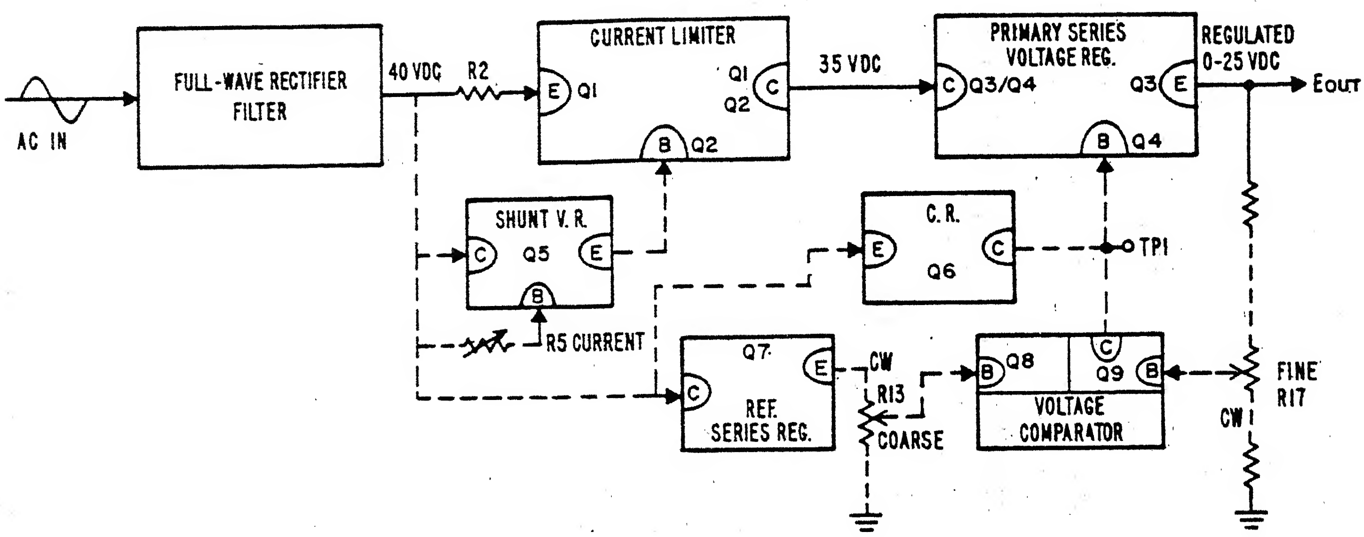
PROGRESS CHECK

Addendum

Lesson 30-2A

Transistor, Voltage and Current Regulators

USE THE DIAGRAM BELOW AND THE FOLD-OUT SCHEMATIC FOR THE TRANSISTOR REGULATOR CARD TO ANSWER QUESTIONS 1, 2, AND 3.

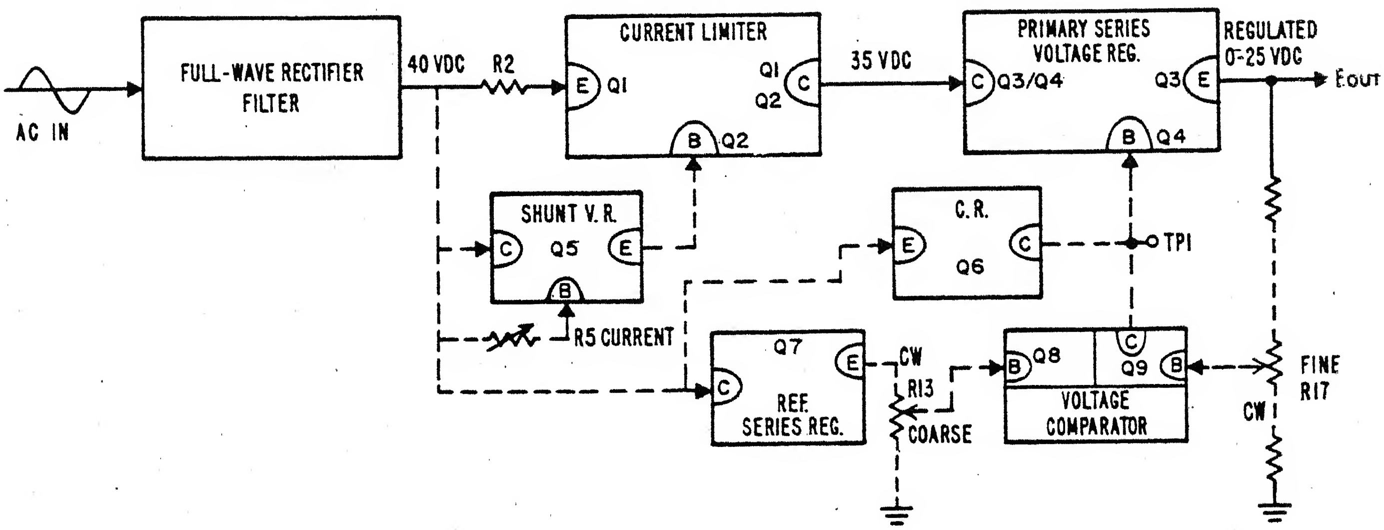


1. The ____________ ____________ regulator stage controls the current limiter and the ____________ ____________ stage controls the primary series voltage regulator.

2. When the load current reaches the limit value, the voltage drop across R2 ____________ (increases, decreases) the forward bias for ________ (Q1, Q5).

3. As the Current control on the front panel of the NIDA power supply trainer is rotated CW, the voltage across Q5 ____________ (increases, decreases) and the maximum current from the regulator ____________ (increases, decreases).

USE THE DIAGRAM BELOW AND THE FOLD-OUT SCHEMATIC FOR THE TRANSISTOR REGULATOR BOARD TO ANSWER QUESTIONS 4, 5, 6, AND 7.



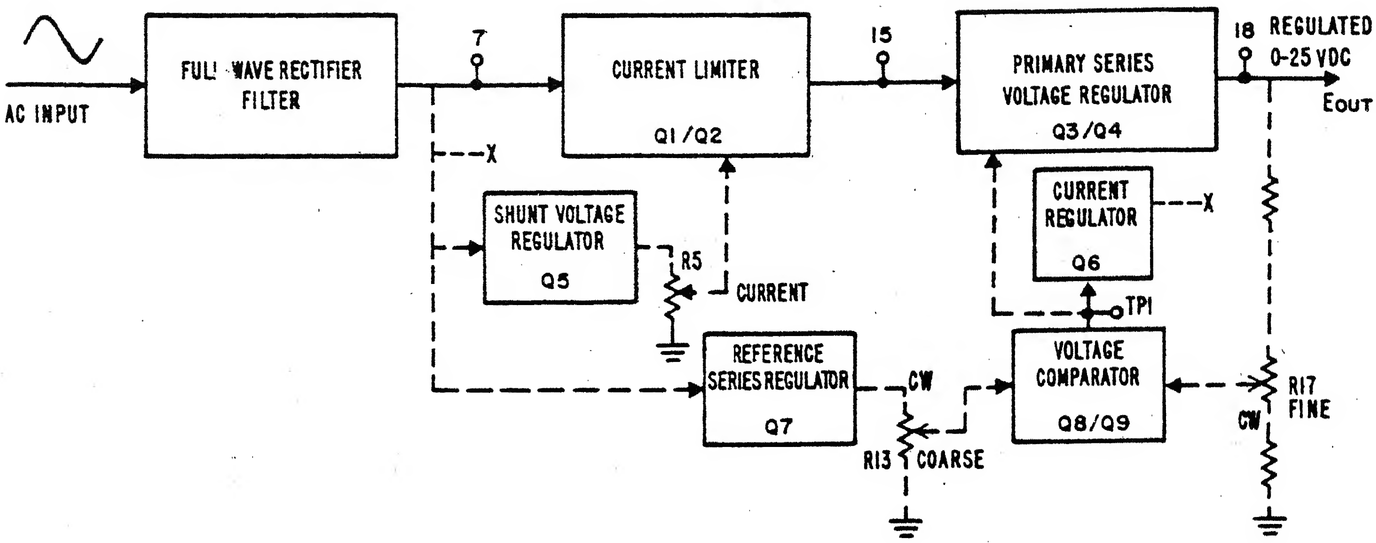
4. The error signal at the base of transistor _____ is compared with the reference voltage at the base of transistor _____ to develop the _______________ signal at TP-1.

5. As the Coarse voltage control on the front panel of the MIDA power supply trainer is rotated CW, the resistance of Q9 ____________________ (increases, decreases) and the resistance of Q4/Q3 ____________________ (increases, decreases).

6. When the Fine voltage control is moved CW, the conduction of Q9 ____________________ (increases, decreases) and the conduction of Q4/Q3 ____________________ (increases, decreases).

7. The "key" to troubleshooting the transistor regulator card requires the use of front panel controls to ____________________ (increase, decrease) the number of suspect stages through the process of ____________________ (elimination, expansion)

USE THE DIAGRAM BELOW AND THE FOLD-OUT SCHEMATIC FOR THE TRANSISTOR REGULATOR BOARD TO ANSWER QUESTIONS 8, 9, AND 10.



8. The "half-split" test point for the main path stages in the transistor regulator is ________, where the expected voltage varies between zero (0) and _______ VDC by rotating control ______.

9. When rotation of R17 produces a small change in the output voltage, but rotation of R13 does not, you would suspect a problem in the

   a. voltage divider or voltage comparator.

   b. reference series voltage regulator or voltage comparator.

   c. current limiter or shunt voltage regulator.

   d. current regulator or current limiter.

10. When the output voltage from the transistor voltage regulator is zero (0), and the voltage at TP-15 is normal, you should measure the voltage at ____ while slowly rotating ________.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 3

SCR Power Supply Circuits

A power supply which provides a maximum amount of power output is required for some transmitters, receivers, computers, radar systems and other electronic equipments. The power supply which provides this high current output with a minimum internal power loss is the silicon controlled rectifier (SCR) type power supply.

The symbols for a regular diode and an SCR are shown in Figure 1. These symbols are provided to help you understand the difference between the two components.

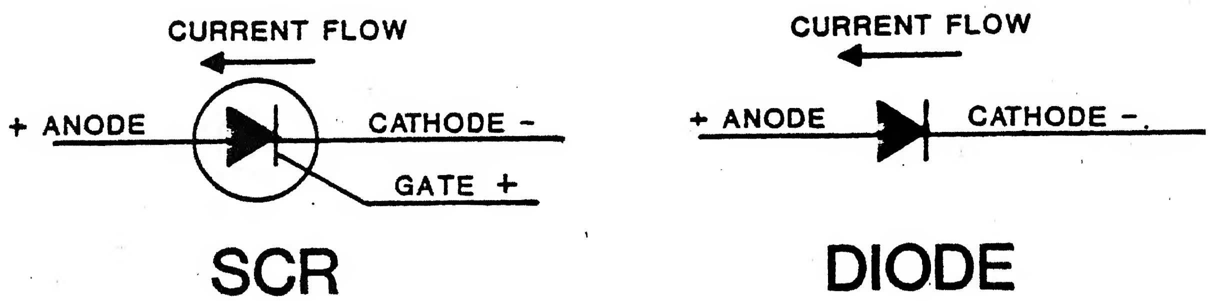


Figure 1

SCHEMATIC SYMBOLS

Both the diode and SCR have a cathode and an anode. However, the SCR has an additional element which is called the gate. The gate provides the triggering or turn-on capability for the SCR.

You already know that neither the diode nor the SCR conduct when they are reversed biased, and therefore block current flow through other components which are connected in series with them.

The difference between the diode and the SCR is that even when the SCR is forward biased, it will not conduct until an adequate positive voltage is applied to its gate. Of course once conducting, it behaves like a diode and continues to conduct until the forward bias is removed or a reverse bias is applied. This gate voltage may be momentary, since a continuous gate voltage is not required to assure continued current flow. If you have difficulty understanding the concept of SCR gating please refer back to Module 25 or study an alternate form of this lesson.

Since the gate has turn-on capability only when the SCR is forward biased, once the SCR is conducting the gate no longer has control over the SCR regardless of the gate potential. The SCR is turned off only when it it is reverse biased or the forward bias has been removed.

The schematics shown in Figure 2 are for a half-wave diode power supply and a half-wave SCR power supply.

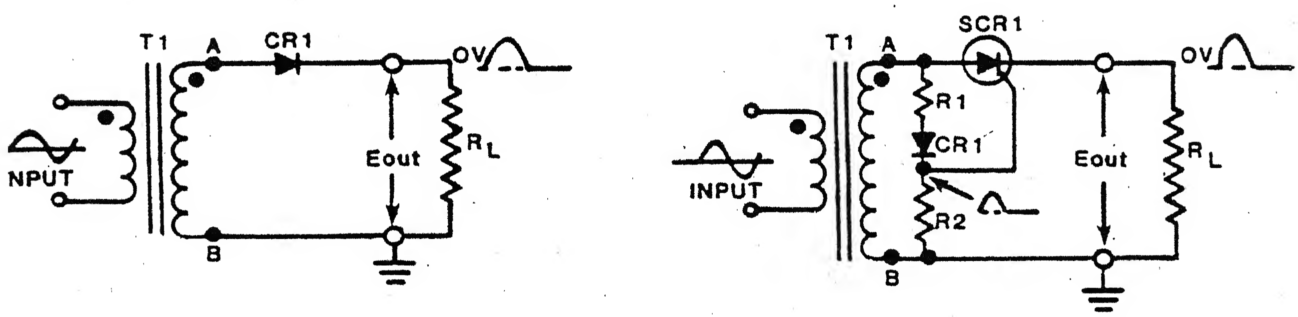


Figure 2

HALF-WAVE DIODE POWER SUPPLY (UNFILTERED)

HALF-WAVE SCR POWER SUPPLY (UNFILTERED)

The SCR power supply is similar to the ordinary diode power supply which you have studied previously. The only difference is that SCRs are used instead of diodes and the SCRs have the capability of controlling the conduction time and the amount of current which ultimately reaches the filter and load. Study the schematics and notice that even though they are essentially identical, several additional components have been added to the SCR power supply. These components, consisting of R1, R2, and CR1, are used to trigger or turn on the SCRs.

The waveforms shown in Figure 3 show pictorially how the SCR operates with an AC input.

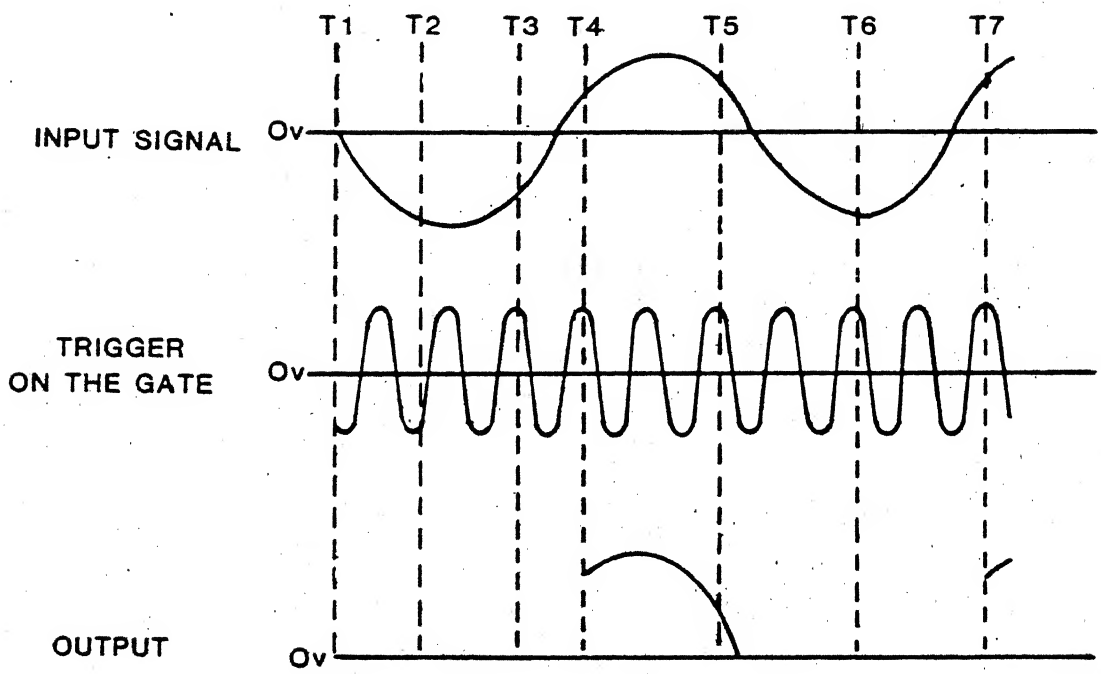


Figure 3

SCR TIMING WAVEFORMS

Notice that as long as the input signal is negative, current cannot flow and consequently there is no output. Even when the input signal becomes positive and the SCR is forward biased, the SCR will not conduct until a positive trigger voltage is applied to the SCR gate. This voltage must equal or exceed the gate or trigger voltage rating of the SCR. SCRs with different trigger voltage ratings are available. Make sure you understand the waveforms shown and the time the SCR conducts and when it stops conducting, before proceeding further with this lesson.

Although half-wave SCR power supplies are seldom used, an understanding of their operation will help you understand how the full-wave SCR power supply operates.

Figure 4 shows the schematic for a half-wave SCR power supply.

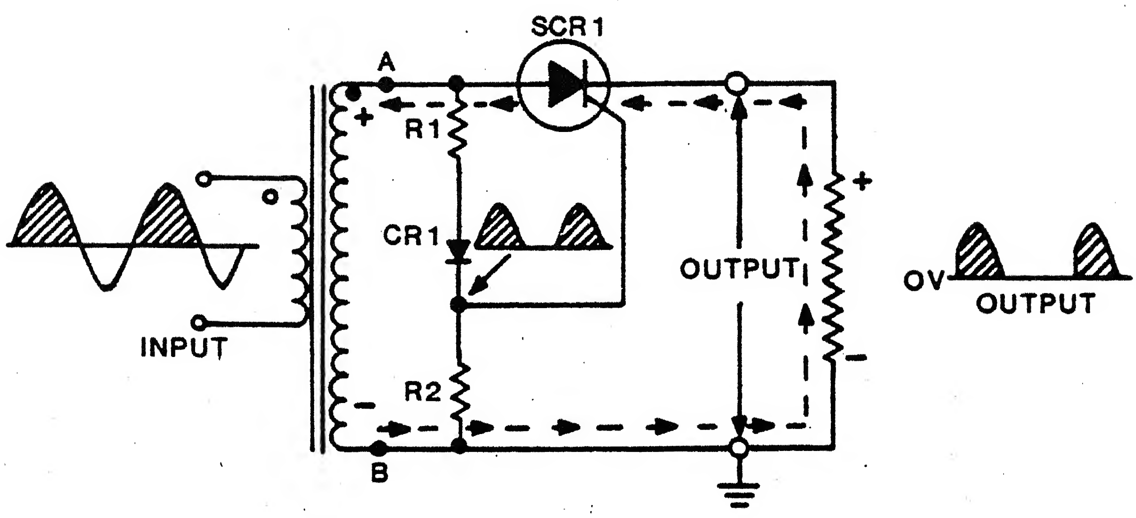


Figure 4

UNFILTERED SCR HALF-WAVE POWER SUPPLY

R1, R2 and CR1 make up a half-wave gating network for the SCR power supply. SCR1 and RL are the half-wave SCR components.

Recall that an SCR will not conduct unless it is forward biased and a positive potential is applied to its gate. Therefore current flows through R1 and R2 only when terminal A of T1 is positive. At this time CR1 is forward biased. When terminal A becomes negative CR1 is reverse biased and current does not flow. Voltage is developed across R2 only during the positive half cycle and the gate triggers the SCR at this time. This means that SCR current can only flow during the positive cycle.

The waveforms shown immediately to the right of the schematic indicate the output of the power supply during positive alternations. Trace the current flow and make sure you understand how this half-wave SCR supply rectifier operates before proceeding further.

Since the gate voltage is dependent on the voltage divider, the firing time of the SCR may be changed by changing the value of the voltage divider resistors. For example, if the resistance of R2 is increased, the gate voltage trigger level on the SCR will be reached sooner, resulting in an earlier SCR turn on. This causes the SCR to conduct for a longer period of time before the positive alternation ends and the SCR again becomes reverse biased. Thus, the output voltage is variable by making R2 a variable resistor.

Waveforms shown in Figure 5 illustrate the effect of different resistance values of R2 and the corresponding output of the SCR. Note particulary that a large value of R2 results in an earlier firing time and that the gate potential and the output is only present during the positive input cycle. This is shown by the two waveforms immediately below the input waveform. Study the other waveforms to make sure you understand what happens when R2 has a small value, and a filter is added to the output.

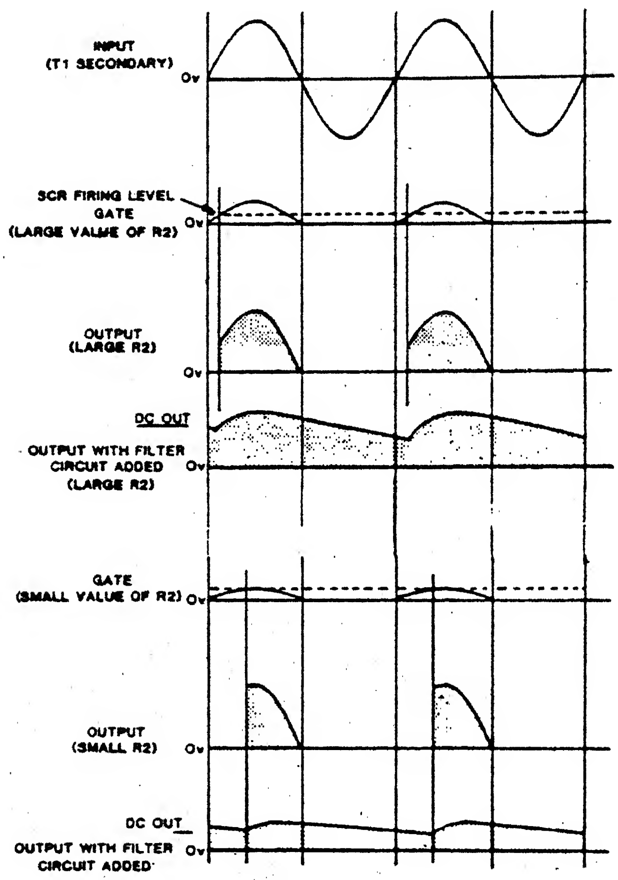


Figure 5

HALF-WAVE SCR WAVEFORMS

Thus far the explanation has been concerned with one-half of a full-wave SCR rectifier. The schematic shown in Figure 6 represents a full-wave SCR rectifier. Recall that the advantage of full-wave rectification is an output which has twice as many pulses and is therefore easier to filter. The gating networks for the SCRs are shown in shaded blocks.

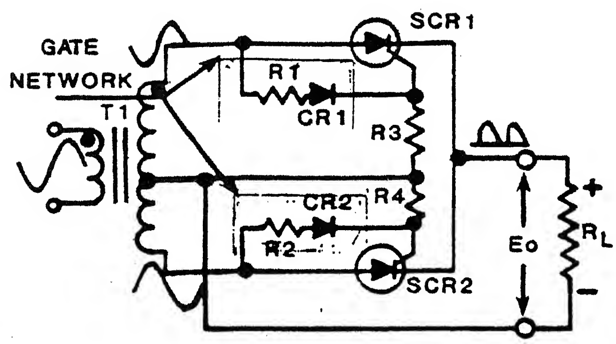


Figure 6

FULL-WAVE SCR POWER SUPPLY

Waveforms shown in Figure 7 illustrate the output of the full-wave SCR rectifier during two complete input cycles. Study the waveforms and schematic shown in Figures 6 and 7 in order to make sure that you understand how the full-wave SCR power supply operates.

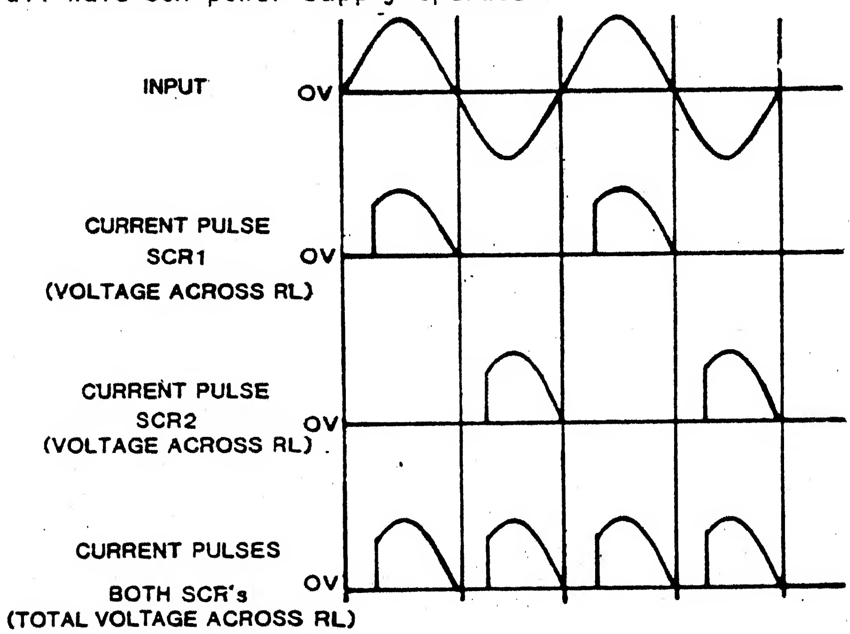


Figure 7

FULL-WAVE SCR RECTIFIER WAVEFORMS

Full-wave SCR power supplies, like full-wave diode power supplies, require a center tapped transformer secondary, and therefore, only half of the transformers secondary potential is utilized at any given time. In order to make full use of the secondary voltage an SCR bridge power supply may be used.

In many respects the SCR bridge power supply is identical to a regular bridge diode power supply. The schematics shown in Figure 8 should acquaint you with the similarities of the two types of power supplies.

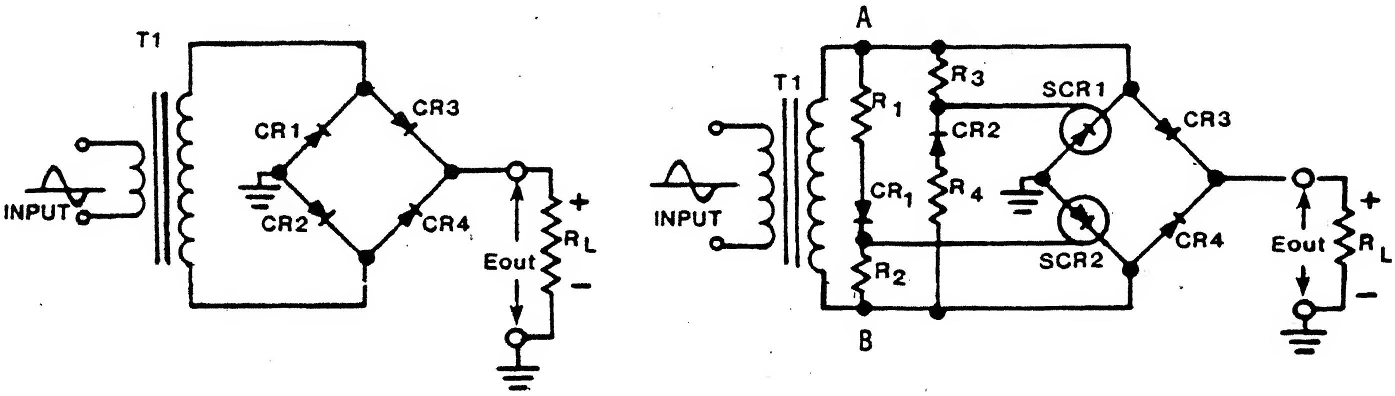


Figure 8

STANDARD DIODE BRIDGE SCR BRIDGE POWER SUPPLY

Notice particularly that the only difference between the two schematics is that the SCR bridge power supply uses two SCRs and gating or triggering networks. Also notice that the SCRs are connected so that one of the SCRs is always in series with load. Stated in simpler terms, one of the SCRs always controls the load current. It may be advantageous if you trace around the circuit and familiarize yourself with the concept that SCR1 is in series with CR4 and SCR2 is in series with CR3.

When terminal A of T1 is positive, CR1, CR3 and SCR2 are forward biased. This also causes current to flow from terminal B of T1, through R2, CR1, R1 and back to terminal A. No additional current flows at this time due to the fact that SCR2 has not been gated or triggered. When the voltage drop across R2 reaches the firing potential for SCR2, the SCR conducts and current flows from terminal B through SCR2 to ground. The current path to terminal A is thereby completed from ground on the bottom of RL through CR3. This current path exists until the polarity of the voltage across the secondary reverses. When terminal A is negative with respect to terminal B, the action is similar. This secondary voltage polarity will forward bias SCR1, CR4 and CR2. Trace the current paths for this alternation to be sure you understand the SCR bridge power supply.

The addition of filter components to any of the SCR power supply circuits will provide a smooth DC output voltage, instead of the pulsating voltage shown on many of the output waveforms. Circuit operation remains the same.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, YOU MAY TAKE THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAME SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

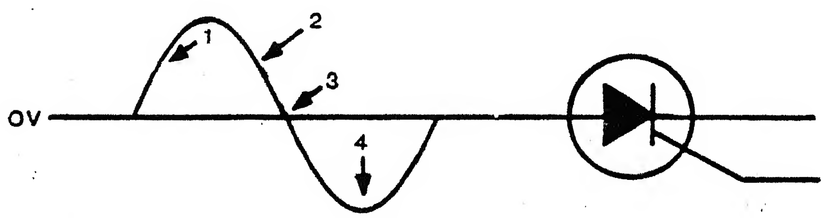
PROGRESS CHECK
LESSON 3

SCR Power Supplies

1. A primary advantage of the SCR bridge power supply is it

   a. uses a center tapped transformer
   b. has low internal power losses
   c. uses a large load resistor
   d. may be connected to produce either a positive or negative output

STUDY THE WAVEFORM SHOWN BELOW IN ORDER TO ANSWER QUESTION 2



2. Assume the SCR is conducting. At what point in the input signal waveform does the SCR turn off?

   a. 1
   b. 2
   c. 3
   d. 4

3. A forward biased SCR will conduct whenever an adequate

   a. negative voltage is applied to the gate
   b. negative voltage is applied to the cathode
   c. positive voltage is applied to the gate
   d. positive voltage is applied to the cathode

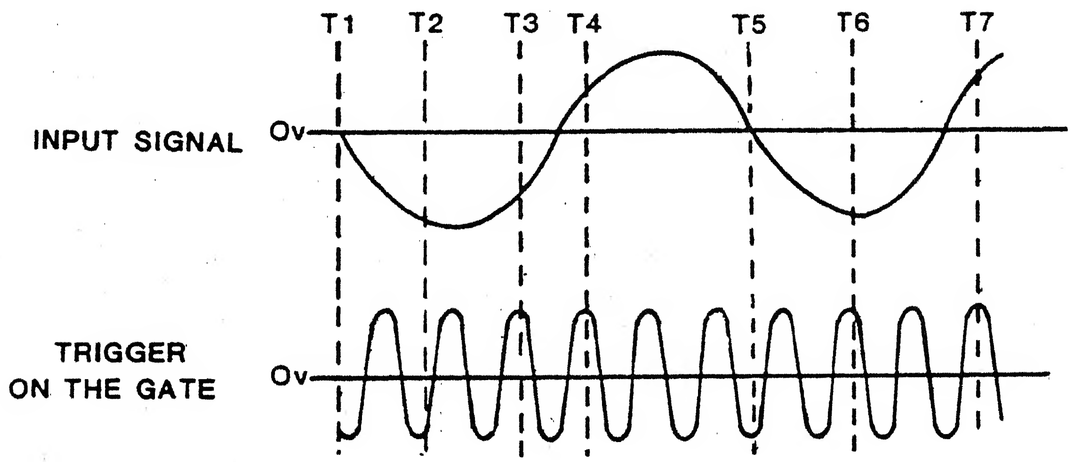
4. A forward biased SCR continues to conduct until

   a. the gate signal is removed
   b. a negative voltage is applied to the gate
   c. the forward bias is removed or a reverse bias is applied
   d. the gate voltage exceeds the SCRs forward bias

5. The SCR is triggered by the gate only when

   a. reversed biased and the gate voltage is positive.
   b. forward biased and the gate voltage is negative.
   c. reverse biased and the gate voltage is both negative and greater than the bias of the SCR.
   d. forward biased and the gate voltage is positive.

STUDY THE WAVEFORMS SHOWN BELOW IN ORDER TO ANSWER QUESTIONS 6 AND 7



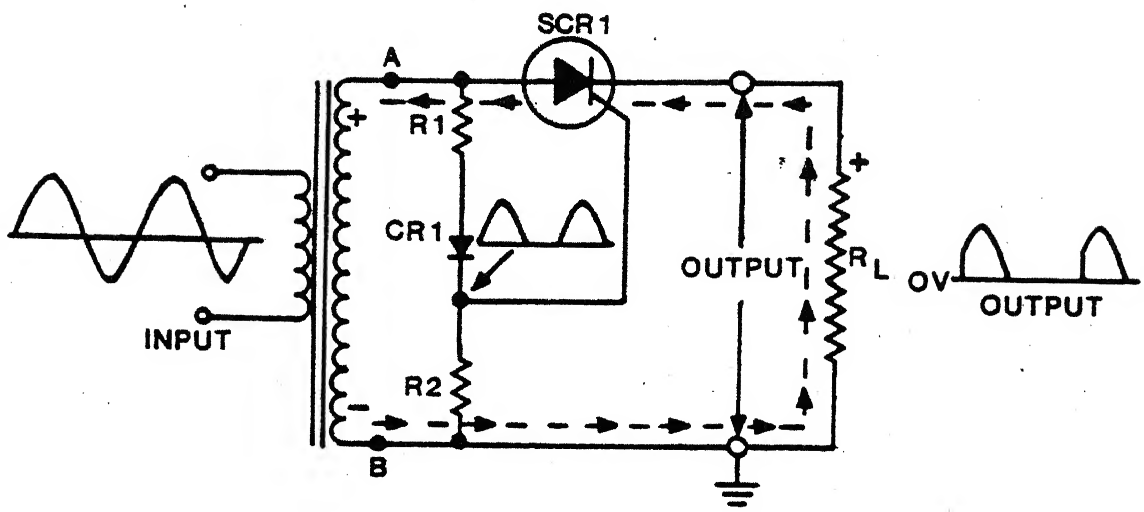
6. The SCR conducts at time(s)

   a. T1
   b. T4 and T7
   c. T6
   d. T2 and T3

7. Once the SCR has been triggered it continues to conduct until time

   a. T3
   b. T4
   c. T5
   d. T6

REFER TO THE FIGURE SHOWN BELOW IN ORDER TO ANSWER QUESTIONS 8 AND 9



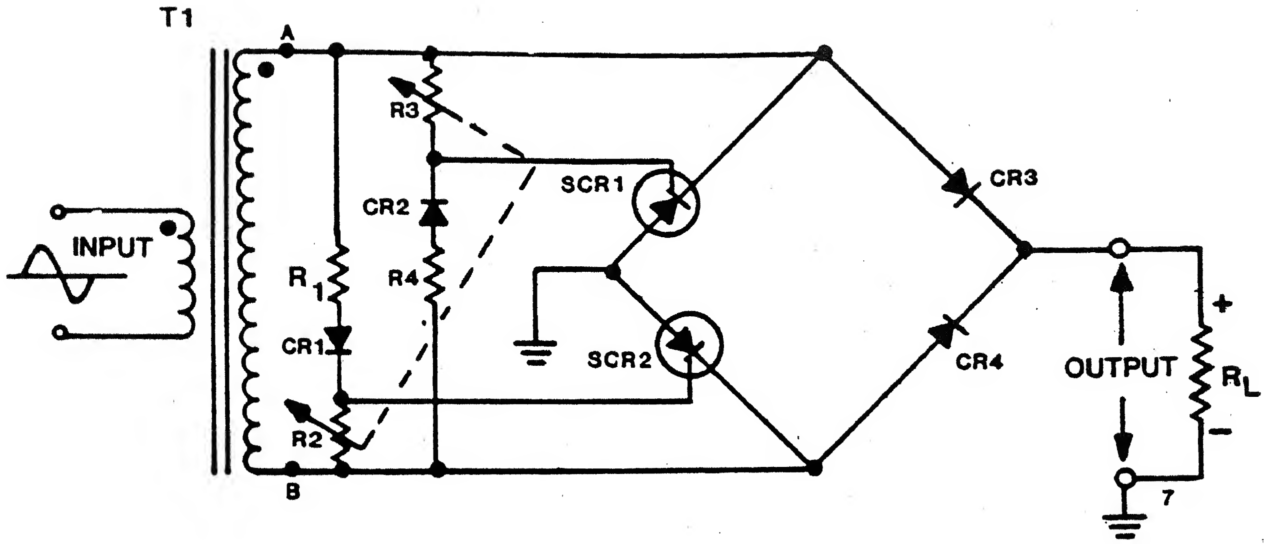
8. When the value of R2 is increased, the SCR will trigger.

   a. later
   b. sooner
   c. when reversed biased
   d. can't tell based on information given

9. When the resistance of R2 is decreased, the average output of this half-wave power supply

   a. increases
   b. decreases
   c. remains the same
   d. cannot be determined based on the information given

REFER TO THE SCHEMATIC BELOW WHEN ANSWERING QUESTIONS 10 AND 11



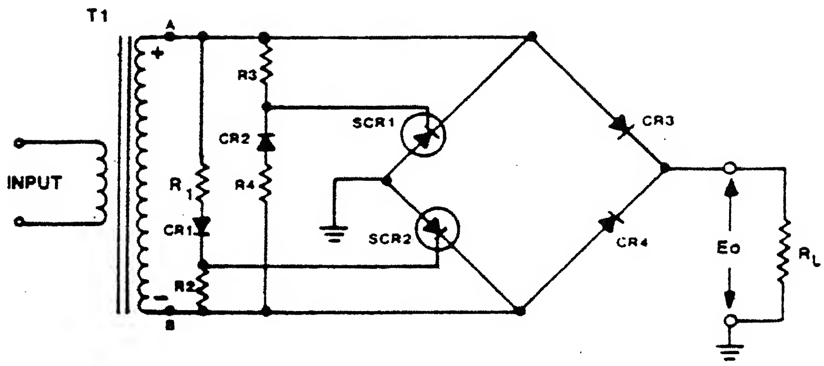
10. Decreasing the value of R2 and R3 results in ________ in the average DC voltage across RL.

    a. a decrease
    b. an increase
    c. no change
    d. none of the above

11. The amount of output voltage is determined by

    a. the conduction time of the SCRs
    b. the input voltage
    c. the different values of R2 and R3
    d. all of the above

REFER TO THE SCHEMATIC SHOWN IN THE FIGURE BELOW IN ORDER TO ANSWER QUESTION 12



12. In the SCR bridge power supply shown, the SCR(s) that will be "gated on" with the polarities shown is/are:

    a. SCR 1
    b. SCR 2
    c. both SCR 1 and 2
    d. none of the above

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY AND FEEL READY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

☆ NOTES ☆

ANSWER SHEET FOR PROGRESS CHECK

Addendum 30-2A

Transistor, Voltage and Current Regulators

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	shunt voltage, voltage comparator	6.	decreases, increa[illegible]
2.	decreases, Q1	7.	decrease, eliminatio[illegible]
3.	increases, increases	8.	TP-15, 35, R5
4.	Q9, Q8, correction	9.	b. reference series voltage regulato[illegible] or voltage comparator
5.	increases, decreases	10.	TP-1, R13, (no voltage at R17)

ANSWER SHEET FOR PROGRESS CHECK

LESSON 3

SCR Power Supplies

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	b.	7.	c.
2.	c.	8.	b.
3.	c.	9.	b.
4.	c.	10.	a.
5.	d.	11.	d.
6.	b.	12.	b.